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Size Measurement Based on Micro-Irregular Components

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Abstract

In order to solve the problems of difficult size detection of micro-irregular components and low measurement accuracy in the manufacturing process of electronic products, the theories and methods of image recognition and visual inspection are used to solve the problems. A visual inspection scheme based on Halcon-based micro-irregular size detection and center coordinate acquisition is proposed. First, on the basis of rough positioning of the component and obtaining the basic position information of the component, a stable detection algorithm based on a specific size of a random location is adopted to realize the size inspection and screening of the component and the acquisition of the center coordinate, and then use the nine-point calibration method Calibrate the camera to obtain the pixel equivalent, and complete the real-time measurement of size information. The experimental results show that the stable detection algorithm of specific calipers based on random positions can significantly improve the accuracy of the measured size information and coordinate information, meet the actual production needs, and provide an effective solution for the size detection and center coordinate acquisition of micro-irregular components.

Keywords

Machine vision; Irregular shape; Template matching; Size measurement; Halcon.

1. Introduction

Electronic components often need to be inspected before product assembly, mainly including the inspection of each component's external dimensions, interface dimensions, flatness, perpendicularity, etc. [1]. At present, for irregularly shaped and easily deformed parts, the traditional measurement suffers from deformation or even damage caused by human factors or environmental factors, which makes it difficult to ensure measurement accuracy and assembly precision. Because the test object material is soft and easily deformed, it is not possible to use clamping devices to fix it in the process of assembly, which makes the position of the part move randomly during the inspection process and increases the difficulty of dimensional inspection. At the same time, in the face of irregularly shaped parts, detection is difficult, measurement accuracy is low, and for the assembly of the wrong components will cause different degrees of rework, greatly reducing production efficiency. The article uses a non-contact inspection method based on machine vision, and the research application takes the mass production workshop as the starting point to propose a specific solution to the problem of difficult positioning detection of small-sized parts with irregular shapes, and the solution also solves the problem of unstable positioning detection of parts due to unclamped parts.

Dimensional inspection based on machine vision has the advantages of non-contact, high efficiency and high accuracy, and is now widely used. Zhao Zhe [1] et al. applied image processing technology to the automatic detection of tiny dimensions, which effectively avoided the measurement errors caused by human factors and significantly improved the measurement

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accuracy; Shan Bo [3] et al. used sub-pixel edge detection as an entry point to improve the accuracy of tiny dimension detection. However, these existing studies are all aimed at dimensional measurement of regularly shaped parts, and have achieved better results in terms of measurement accuracy, but there are limitations for dimensional measurement of irregular parts, and there are still shortcomings in terms of detection range and detection speed. Therefore, the article proposes a dimensional inspection method for irregular parts with unstable positions using machine vision as the basic theory, and builds an experimental platform using Halcon and Visual Studio 2013 to verify the effectiveness of this dimensional inspection method for miniature irregular parts.

2. Vision Measurement Solution for Micro Irregular Components

2.1. Micro component vision measurement principle

For an electronic component in automatic assembly, it is necessary to quickly and accurately measure the size and center position coordinates of the irregularly shaped assembly patch, and then transmit the position information to the robot to achieve efficient and accurate assembly of the electronic component. The inspection object is the assembly patch as shown in Figure 1.

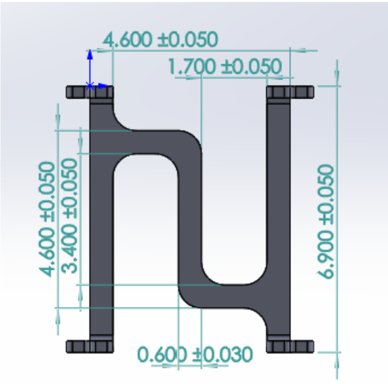

Fig. 1 Assembling the patch

Taking the detection of the size of the assembly patch and the acquisition of the position coordinates as the starting point, and with the aim of improving the assembly accuracy, the following analysis is made on the assembly patch using image processing theory.

(1) In order to reduce the noise in the image and prevent image distortion, the image needs to be filtered and noise reduced.

(2) After the noise reduction process, the image is segmented by other image pre-processing means to obtain the complete and independent target element information.

(3) After obtaining the target elements, the target contours are extracted and template matching is performed to obtain the approximate coordinate information of the components and to determine whether the robot end-effector is attached to the patch.

(4) For the dimensions of irregularly shaped parts, linear inspection calipers and line-to-line distances are adopted for dimensional measurement.

(5) In order to avoid unstable detection due to the randomness of the part's position during the inspection process, the position information of the caliper and the rough position information obtained by template matching are bound to obtain stable detection results.

Therefore, in response to these problems, the template matching is done on the patch before the dimensional inspection, not only for the judgment of the presence or absence, but also for the coarse positioning of the patch, which makes the caliper inspection to obtain stable and straight information, and then obtain more accurate dimensional and coordinate information. The system schematic diagram is shown in Figure 2.

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2.2. Micro Component Vision Positioning Inspection Platform

The size detection system consists of two parts: software and hardware. The software is developed by Halcon in conjunction with Visual Studio 2013 for image processing algorithm and interface programming. Due to Halcon's powerful analysis capability and rich image processing related operators, it can complete the writing of the above image processing algorithm and realize the detection function; Visual Studio 2013 writes the human-computer interaction interface. The hardware includes: camera, lens, light source, PC, manipulator and other parts, as shown in Figure 3. The corresponding hardware selection is: industrial camera Basler acA2500-14gm; lens Computar- M5018-MP2; light source is 15 degrees ring light (blue, strobe), inner diameter 47 mm, outer diameter 92 mm.

3. Image pre-processing of micro electronic components

The image acquisition assistant in Halcon software is used to obtain a real-time image acquisition screen of the whole camera, and a series of image pre-processing: median filtering, dynamic threshold segmentation, morphological processing and other algorithms are used to express the "target area" more clearly according to the acquired image situation.

3.1. Median filtering

Large and small white noise can be clearly seen in the image, and if the noise is not filtered but directly detected by edge detection, it will have a great impact on the measurement results and thus reduce the accuracy of the measurement [4]. In order to obtain clearer edge features, this pretzel noise needs to be processed. For the pepper noise, the median filter has a good suppression effect on it, and also does not blur the image too severely as the mean filter does. The processing results are shown in Figure 4.

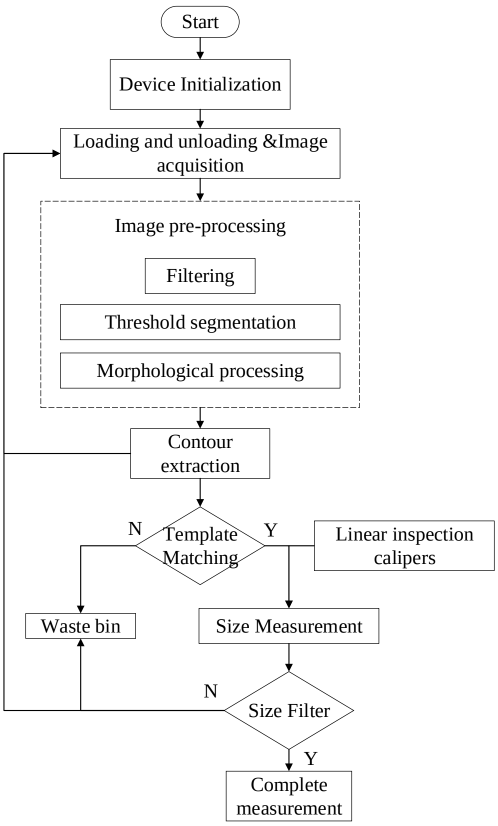

Fig. 2 System detection schematic

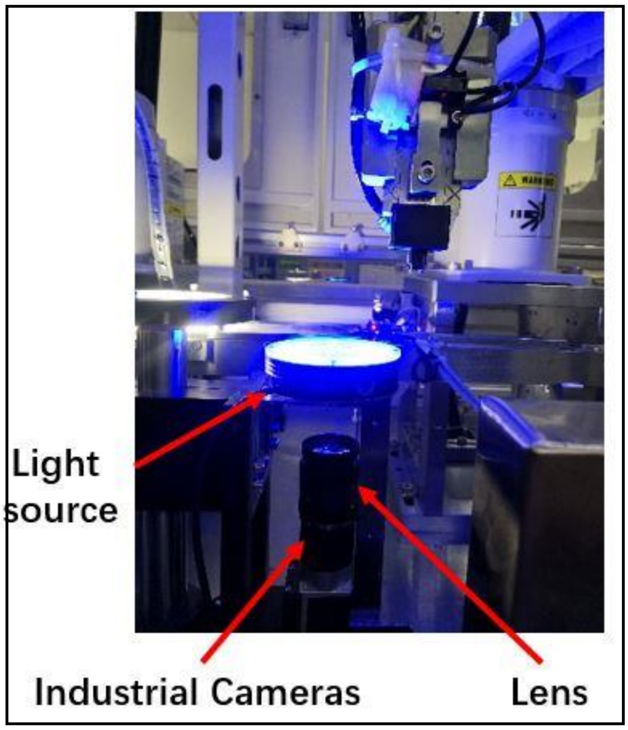

Fig. 3 Hardware system physical diagram

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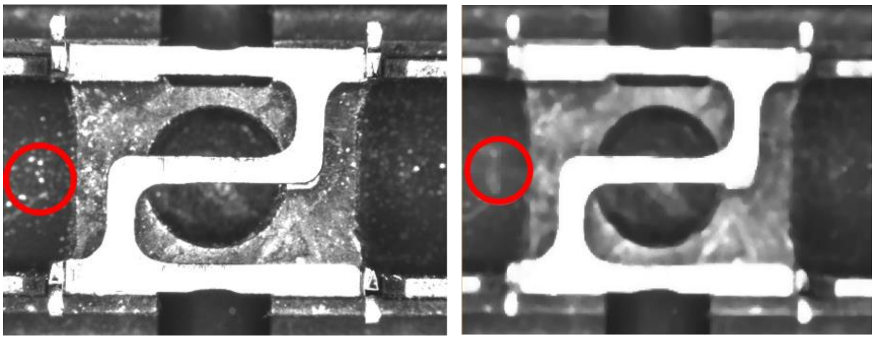


a) Original image b) Median filtered image

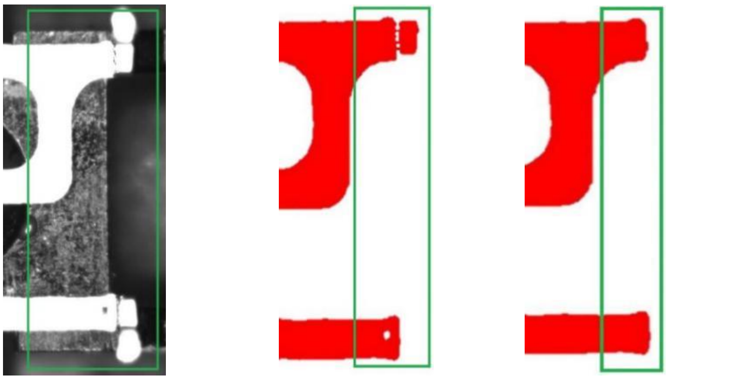
Fig. 4 Median filtering comparison chart

3.2. Morphological processing

After the filtering process, it can be seen that the target area is brightened, and the image can be processed by threshold segmentation after there is an obvious brightness contrast. It cannot be removed by threshold segmentation. It is impossible to remove it by threshold segmentation. It has a great interference to the subsequent contour extraction, so morphological processing is needed to eliminate and supplement this part, and the article adopts the open operation. The opening operation is an erosion and then expansion operation, which generally smooths the contour of the object, breaks the narrow connections or eliminates the thin spikes. The result after using the opening_circle() operator is shown in Figure 5-c).

4. Template Matching

After a series of processing by noise reduction filtering, threshold segmentation and morphological processing, the "target region" is obtained and then the contour features are detected and extracted by the edge detection operator. After the processing of Canny operator, the extracted contours are filtered, and a complete contour line is obtained by fitting the filtered contour line. The contour line is used as a template for template matching and coarse positioning of the patch to be assembled.



a) Original image b) Before processing c) After processing

Fig. 5 Comparison before and after opening the operation

4.1. Shape feature extraction

Edge is the most basic feature of an image, and the image edge is the set of those pixels that have a jump or roof change in the gray level of surrounding pixels [4], and the relevant set of edge pixels can be obtained by applying some computational methods. The extraction of the patch contour is achieved by fitting the extracted contour with the least squares linear fitting algorithm using the Canny edge detection operator, which is the first-order derivative of the

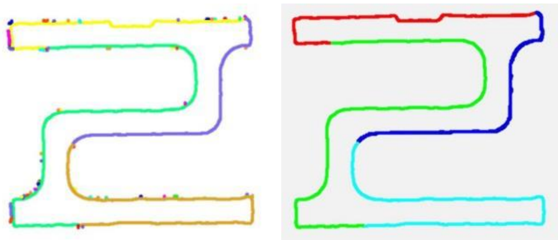
Gaussian function and has good signal-to-noise ratio and detection properties compared to the roberts operator, sobel operator, and prewitt operator. It filters the image using the first-order differentiation of Gaussian function and obtains the magnitude $|Y|$ and direction θ of each pixel gradient as:

$$|Y| = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial f}\right)^2} \tag{1}$$

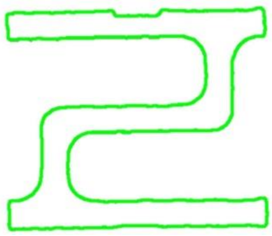
$$\theta = \tan^{-1}\left[\frac{\partial f/\partial y}{\partial f/\partial x}\right] \tag{2}$$

where the equation: f is the image grayscale value.

As shown in Figure 6-a), the detection results are shown using the Canny edge detection operator.



a)Canny Edge Detection b) Edge Profile Screening



c) Complete edge profile

Fig. 6 Schematic diagram of algorithm detection

After the detection and extraction of the contour by the canny operator, in Figure 6-a), it can be seen that some interference contours are detected and the contour lines in the target area are not continuous, so after extracting the contour features, in order to obtain a clearer and more complete contour for template creation, the contour in Figure 6-a) needs to be processed.

By setting the parameters of the operator select_shape_xld(), limiting the length range of contour lines, the patch contour lines can be filtered out, as shown in Figure 6-b), and then it is necessary to use the operator union_adjacent_contours_xld() to connect the patch contours to get the complete patch contour lines, as Figure 6-c) is shown. The irregular contours are created as templates and the template information is saved for subsequent template matching.

4.2. Template Matching

The template matching algorithm used in the article is based on the shape matching algorithm, and its general algorithmic principle is the process of creating a template and matching the template [5]. Firstly, the template is created for the extracted patch contour; next, from overlapping the upper left corner point of the template with the upper left corner point to be matched, the template searches for a piece of the same size in the original image for the convolution operation; then it is panned to the next pixel point and continues the convolution operation; when all the positions have undergone the convolution operation, the region with the smallest difference obtained is the target of matching.

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The result of template matching is not only to obtain the center coordinates and rotation angle of the patch, but also to detect the presence of the patch in the robot end-effector, and the feedback from the system on the detection result will indirectly influence the "direction" of the next operation of the production line. The matching result is shown in Figure 7.

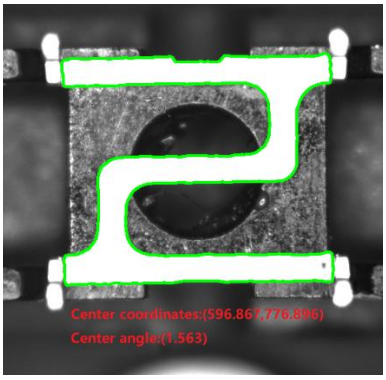

Fig. 7 Matching results show

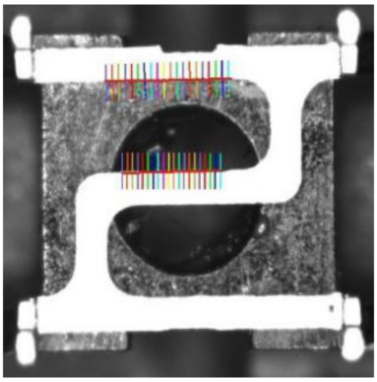

Fig. 8 Calipers of straight line inspection

5. Calipers of straight line inspection

The dimensional inspection involved in other scholars' studies is mainly for regular shapes, and such an inspection scheme is not applicable to the dimensional inspection of irregularly shaped parts. Therefore, for irregular shapes, the relevant contour lines of the dimensions to be inspected, a linear inspection caliper is created to detect the linear information of the relevant dimensions, and the dimensional information is obtained by finding the distance between points to lines and lines to lines.

5.1. Principle of straight line inspection calipers

Edge point detection based on a one-dimensional pixel sequence with gray level leap is a simple and stable method for dimensional measurement [6]. By forming a rectangular to-be-detected caliper, this detection caliper utilizes a number of small edge detection rectangles, which are fitted to find the target contour after detecting the edge points one by one. As an example, the detection size shown in Figure 8 is a pair of search regions with directions, placed among the two edges of the size to be detected, and the appropriate direction is selected according to the gray leap of the edge to be measured in the image, and the two edges of the size to be measured are detected, and the maximum or minimum distance between the two line segments is calculated as the size value of this detection.

5.2. Stable linear detection

Due to the complex environment in the production line, the inspection results of the ordinary linear inspection calipers will change with the different positions of the patch in the picture. Because, the linear inspection caliper will be fixed at the position after it is placed, if the position of the component is moved or the component is rotated, the inspection result will change accordingly and the inspection stability will be reduced. As shown in Figure 9, the position of the assembly patch is shifted will have an impact on the caliper detection results, such as not detecting the edge, detecting multiple line edges, detecting non-target edge tilt, etc. Therefore, the ordinary linear inspection calipers are suitable for inspection of single pictures or fixed positions with fixtures, etc. relative to stationary objects.

For this production line, due to the small and soft nature of the patch, the use of fixture fixation is not desirable, so the nozzle is used to absorb the assembled patch and place it in a certain detection area, which means that in each captured picture, the position of the linear inspection caliper is shifted relative to the position at the time of the first program test, and there is a certain degree of chance in the results of linear inspection. Therefore, in order to detect the required edge straight line at the random patch position, it is necessary to combine the above-mentioned template matching and caliper detection to cooperate with each other to complete the stable edge detection.

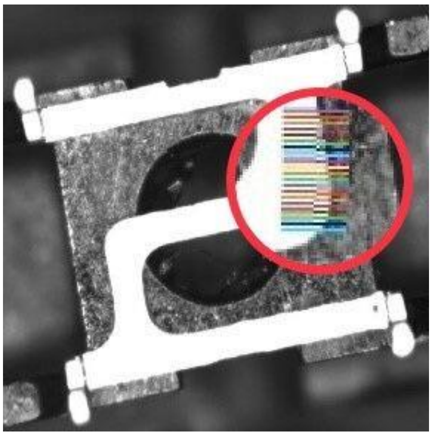

Fig. 9 Caliper does not move with the component effect

The method is to establish a relative position OffsetRow and OffsetColumn between the center coordinates of the template and the center coordinates of the caliper to "bind" the template and the detection caliper into a new template. Finally, as the shape-based template matching operator convolves in the process of detecting the image, the smallest difference region is also the matching target, and the caliper will appear at the preset position of the edge to be detected while matching the result, and at the same time, with the affine change of the template, the relative positions of the template and caliper OffsetRow and OffsetColumn are affine by the operator affine_trans_pixel and OffsetColumn for affine transformation, so as to complete a template matching algorithm similar to the template plus detection caliper into a new template, the final caliper detection module will move with the position of the patch and move, so that the edge can be stably detected straight line, as shown in Figure 10), to achieve the effect of the edge position moves while the detection caliper follows the movement.

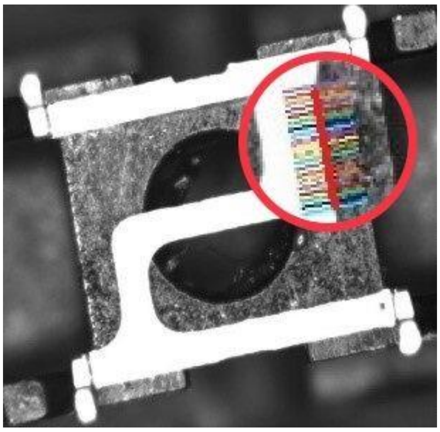

Fig. 10 Caliper with the effect of component movement

5.3. Camera calibration

After obtaining the stable edges, the edges to be measured can be extracted by 7 calipers. The shortest distance between lines is obtained by the operator distance_ss for dimension 1 composed of caliper 1 and caliper 2, dimension 2 composed of caliper 3 and caliper 4, and dimension 3 composed of caliper 1 and caliper 5. These three sets of dimensions are measured to exclude the thin edges of the patch from bending due to deformation during the assembly process, thus causing this assembly to fail. The caliper group composed of calipers 2, 3, 6, 7, through the intersection_lines to obtain the intersection of two lines to obtain the intersection of the four vertices of a rectangle, through the vertices can be obtained to the diagonal of the

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rectangle, but also to obtain the diagonal center point, that is, the center of the assembly patch coordinates. This is shown in Figure 11.

Before this, the measured dimension data are the actual dimensions. But in the process of image processing, the data processed and detected are pixel dimensions, so calibration is needed to realize the conversion between pixel dimensions and actual dimensions, and the pixel equivalent is the actual dimension represented by a unit pixel. At the same time, the calibration can obtain the internal and external parameters of the camera, and eliminate the influence of the aberration of the camera lens itself on the measurement results. The article adopts the nine-point calibration method, the calibration process only needs to use a printout of nine serial numbered points, and obtain the pixel equivalent and parameter matrix by obtaining the pixel coordinates of the nine points and obtaining the probe coordinates at the end-effector of the robot in the order of the pixel coordinates and corresponding to them one by one. This calibration method is not only easy to operate, flexible and convenient to use, but also has high accuracy and good robustness. Finally, the pixel unit size of the detection is converted into the actual size and actual center coordinates using the obtained pixel equivalents. As shown in Figure 11.

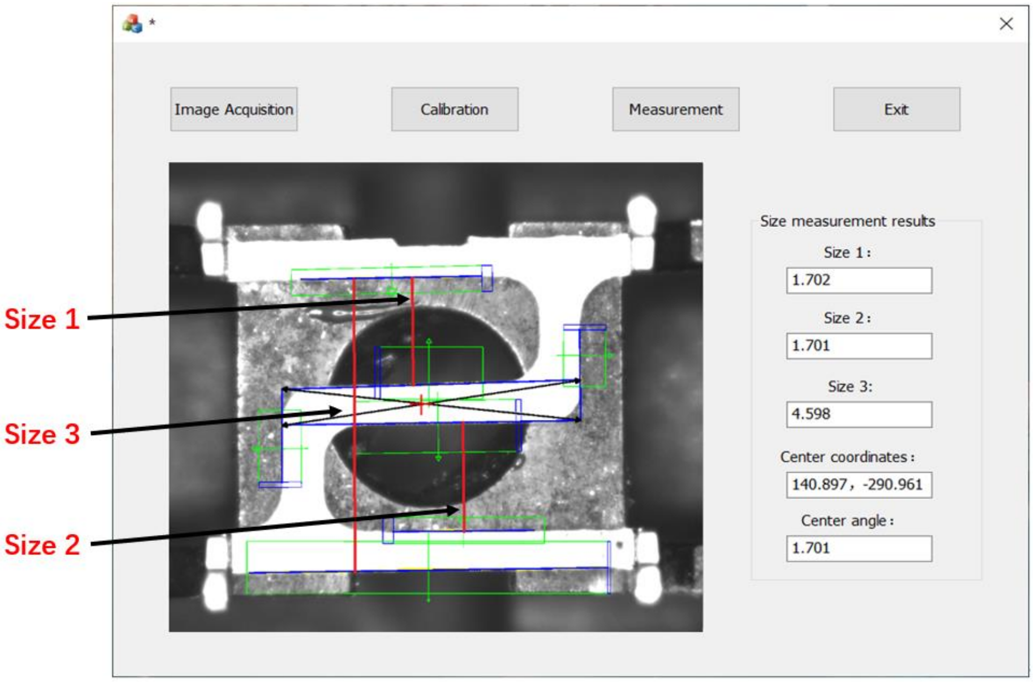
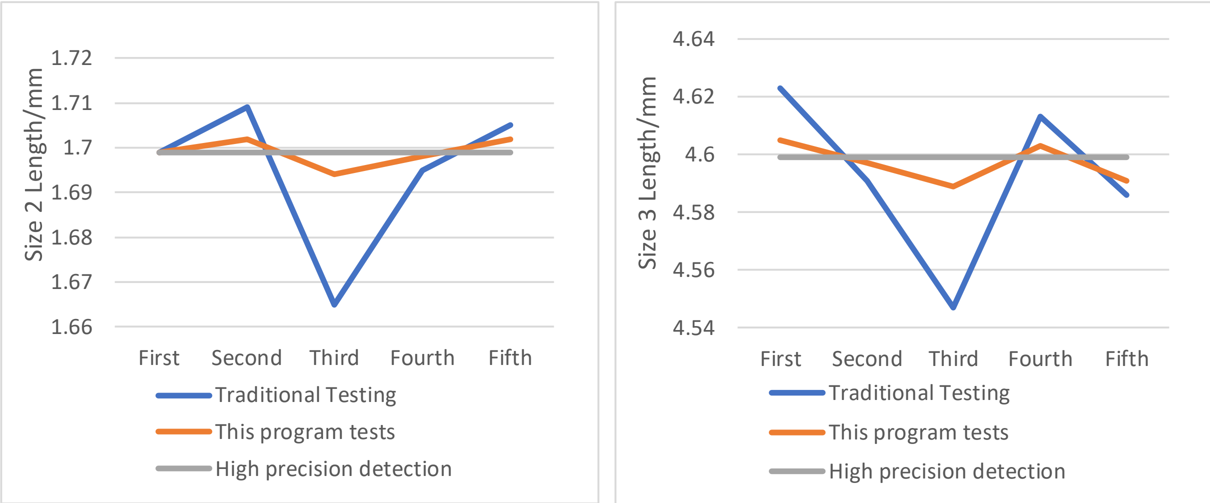


Fig. 11 The test results show

6. Experimental testing and analysis

In order to verify the effectiveness and stability of the system, a patch that has been inspected with high precision and meets the assembly dimensions was used as the test component, and five measurements were made on the component's size 2 and size 3, respectively, and the results are shown in Figure 12.

Whether size 2 or size 3, as can be seen in Figure 12, the results of the use of the subject of the inspection program compared to the results of the traditional inspection of higher accuracy, and closer to the standard inspection line, which in the third experimental test due to the position of the component offset, the results of both methods have caused some impact. However, the results of the traditional inspection scheme have exceeded the inspection accuracy, which is due to the fact that after the position of the part has changed, but the position of the linear inspection caliper has not shifted, resulting in a linear line detected by the linear inspection caliper that is not the edge of the composition size 2. However, the optimized linear inspection caliper will move with the position of the component so that the pair of straight edges of dimension 2 will be accurately detected and accurate detection of the dimension will be achieved. Although there is a certain error compared to the standard size, it meets the field inspection accuracy requirements and verifies the effectiveness of the system.



a) Size 2 data comparison b) Size 3 data comparison

Fig. 12 Realization of the results show

7. Conclusion

In the process of dimensional inspection of miniature irregular components, the paper uses Halcon software to roughly locate the irregular parts through image pre-processing, contour extraction, and template matching, and then "binds" the center coordinates of the template matching to the coordinates of the inspection calipers to obtain more accurate dimensional inspection results and center coordinates. The system is designed to move the caliper along with the template matching result to obtain more accurate dimensional inspection results and center coordinates. The experimental results show that the accuracy and success rate of dimensional inspection of this system are obviously improved, and the solution can realize fast, accurate and real-time non-contact miniature irregular component measurement, which can be applied to the actual production to improve the production efficiency [7], and has certain guiding significance for robot guidance, assembly and dimensional measurement.

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